# Use of Remote Sensing , GIS and Field Survey Techniques for Forest Fire Mapping in the Upper Nan Watershed, Northern Thailand

S. Sangawongse[a]; P. Pinkantayonk[b] and W. Nawapramote[c]

[a]Department of Geography, Faculty of Social Sciences, Chiang Mai University, Thailand

[b]Huaykaew Watershed Development Office, The Royal Forestry Department, Chiang Mai ,Thailand 50200

[c] Huaykaew Watershed Development Office, The Royal Forestry Department, Chiang Mai, Thailand 50200

**Abstract:** The Nan watershed in northern Thailand has undergone severe forest fires at a regular intervals. Fires have brought a lot of damage to many potential resource areas, and have had a negative impact on the forest ecosystem. The project manager overlooking this study has examined the use of geoinformatic techniques for accurately mapping and quantifying the damaged areas. Major approaches undertaken in this study are: (1) image classification of Landsat-7 Enhanced Thematic Mapper Plus (ETM+) data using the supervised Maximum Likelihood Classification; (2) managing and analysing a GIS data and (3) ground surveys using a Global Positioning System (GPS) for collecting the training sets and ground control points. The result shows that existing burnt areas account for about 21 sq.km; occupying 2 % of the study area, whilst forest, agriculture, grassland, and scrub occupied 54 %, 10 %, 20 % and 2.5 % respectively. The burnt areas are separated well from other land cover types. The overall accuracy of detection of burnt areas is about 98 %.

***Keywords:*** *geoinformatics; Enhanced Thematic Mapper Plus (ETM+); Geographic Information Systems (GIS); Global Positioning System (GPS); Maximum Likelihood Classification; Training sets*

## 1. INTRODUCTION

The upper Nan Watershed Management Project is an international collaboration between the Royal Thai Forestry Department (RFD) and the Danish International Development Assistance (DANIDA). It aims to apply the concept of sustainable resource development and the improvement of the quality of life of the local residents using a participatory process.

In this region, forest fires occur frequently during the summer season (March- May). They affect large areas every year (Nan DANIDA Office, 2002). The susceptibility to forest fires of the project area is mainly due to three factors: (1) the typical dry and hot summer climate; (2) the characteristics of the natural vegetation, which is mainly deciduous, and made up of bamboo and shrubs: (3) the human influences. These last include performance of agricultural activities including livestock ranching. All of these three factors accelerate the spread of fire in forested land areas. In a previous study in 1998 of forest fire using satellite data, burnt areas accounted for about 209 square kilometers (21 %) of the project area. This study of forest fires in 2002 was carried out in order to evaluate the work on forest fire risk mapping from previous years. This paper reports on the application of geoinformatics techniques, which integrate remote sensing, GIS and use of GPS for forest fire mapping. This study was carried out to fulfill two objectives: (1) to apply the satellite data to accurately mapping the areas burnt by fire and then (2) to apply the results to carry out effective forest resource management and planning within the upper Nan watershed.

## 2. DATA SOURCES

Landsat-7 ETM+ and other data, including GIS vector data, were applied to mapping forest fires. GIS layers, consisting of transportation networks, drainage, a digital elevation model (DEM) and point (e.g. village location) data were used as the source of spatial information for classifying land into cover types. Two Landsat-7 data sets, recorded on 30/12/2001 and 5/4/ 2002, were acquired from GISTDA (Geo-Informatics and

Space Technology Development Agency (Public Organization) in Bangkok.

Landsat-7 is a recent version US Earth Resource Satellite, which was launched in April 1999(http://www.gistda.or.th). The ETM+ instrument is an eight-band multispectral scanning radiometer capable of providing high-resolution image information of the Earth's surface. It detects spectrally-filtered radiation at visible, near-infrared, short wave, and thermal infrared frequency bands from the sun-lit Earth. Nominal ground sample distances or "pixel" sizes are 15 meters in the panchromatic band (PAN); 30 meters in the 6 visible, near and short wave infrared bands; and 60 meters in the thermal infrared band (http://landsat7.usgs.gov/about.html).

The GIS data was mainly obtained from the Watershed Management Unit in Chiang Mai. Data manipulation was done before using it for this study.

## 3. STUDY AREA

The study area is located in Nan Province of northern Thailand. It lies between 18 ° 59' and 19 ° 33' N Latitude and between 100° 32′ and 100 °51 ' E Longitude. Its elevation ranges between 200 and 700 meters above an Average Sea Level. It encompasses 6 forest management units, as shown in Table 1 and Figure 1. The total study area is about 1,000 square kilometers.

**Table 1: Forest Management Unit in the Upper Nan Watershed (2002)**

| Unit No | Name of Forest Unit | Responsible Area (sq.km) |
|---|---|---|
| 1 | Khun Nam Prik | 164 |
| 2 | Huay Nam Yod | 132 |
| 3 | Nam Yao | 130 |
| 4 | Nam Hui | 284 |
| 5 | Nam Han | 191 |
| 6 | Nam Sobsai | 108 |
| Total | | 1007 |

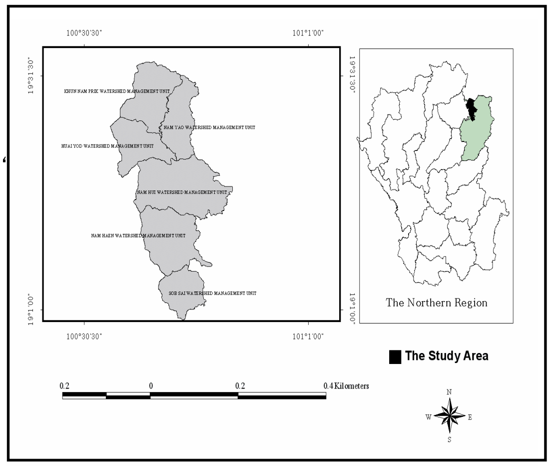


**Figure 1: Location of the Study Area**

## 4. METHODOLOGY

This study is based on a combination of remote sensing, GIS and field survey techniques. Version 4.5 of the WINCHIP image processing software, developed by Copenhagen University in 1999 was the main software used for analyzing the ETM+ data. GIS analysis was based on ArcView version 3.2 (ESRI, 1996). Image processing of satellite data included the following steps:

### 4.1. Geometric Correction of the Satellite Data

This procedure was undertaken to avoid geometric distortions in the satellite images. It involved the selection of suitable Ground Control Points (GCPs), determination of parameters, and resampling (Japan Association on Remote Sensing, 1993).

Most of the GCPs were obtained from the 1992 1:50,000 scale Royal Thai Survey Department topographic maps, which are the base map used for referencing spatial data by many government organizations in Thailand. Ground Control Points were one of a number of parameters including calibration of sensors, atmospheric conditions, etc used to remove the external distortions caused by the earth's curvature, terrain displacement, and other discrepancies in the image data (Meijerink, et.al., 1994).

The April image was selected as the base for this rectification because it was clearer than the December image, making it easy to match GCPs on the reference map and in the satellite image. It was found that 11 GCPs were found to be the best for rectifying the image using the second order polynomial transformation. This was indicated by a low Root Mean Square Error (RMS) of around 0.02. The pixel size was resampled to 25 meters for all image data.

The geometric correction of the December image was done by co-registering to the rectified April image, based on pattern recognition between images. Fifteen GCPs were used for co-registering these images. The RMS for this image was 0.37. For the purposes of overlaying, the pixel size in the December image was also standardized at 25 meters.

### 4.2. Developing Land Use Classification Scheme

The goal in developing the classification scheme is to accurately label the spectral classes found in the imagery as corresponding to specific land uses or ecosystem functions observable on the ground (Wilkie and Finn, 1997). This study adopts a land use classification scheme for use with remotely sensed data (Andersen, et. al., 1976), which classifies land cover into 8 major categories: Forest, Agricultural, Residential, Bare land, Grassland, Tundra Wetland and Water Bodies. The reflectance of ground cover in the study area was divided into 6 major types according to information from a field survey in October 2002. These are listed in Table 2.

**Table 2: Land Use Classification Scheme**

| Land Cover | Level 2 |
|---|---|
| 1. Forestland | - Dry Evergreen Forest<br>- Mixed Deciduous Forest |
| 2.Secondary Forest | - Regrowth<br>- Bamboo Forest |
| 3.Disturbed Forest | - Scrub<br>- Grass |
| 4. Agriculture | - Paddy field<br>- Mixed crops<br>- Mixed orchards |
| 5. Burnt | Burnt |
| 6. Others | - Built-up areas<br>- Water Bodies |

### 4.3. Image Classification

Digital image classification is undertaken to assign pixels or groups of pixels to different categories, according to the degree of similarity of their brightness values in each spectral band. The supervised approach, which is well known and used commonly by many operators in image classification, was also used in this study. The success of image classification relies on the use of optimum bands, and the quality of the image data, which has been geometrically and radiometrically corrected with acceptable accuracy, and the validity of the training sets and the classification methods.

#### 4.3.1 Selection of optimum bands

There are many different ways to select the optimum bands, such as the use of optimum index factor (OIF) (Chavez, *et al*.,1984) and Principal Components Analysis (PCA) of bands (Horler and Ahern, 1986). For this classification, bands 2,3,4,5 and 6 were chosen. Band 2 of the visible portion of the electromagnetic spectrum (0.52-0.60 $\mu$m) gives blue reflectance, which is suitable for discriminating green plants. Band 3 (0.63-0.69 $\mu$m) is sensitive to chlorophyll absorption, which is good for delineating vegetation types. The near infrared band (0.75-0.90 $\mu$m) has a great potential for delineating between land and water, because most healthy plants give high reflectance in this band. The middle infrared bands (bands 5 and 7) are best used for obtaining information on soil moisture conditions and a geological structure. The thermal band or band 6 (10.4-12.5 $\mu$m) was specially chosen for mapping forest fire in this study.

#### 4.3.2 Reduction of the topographic effects

The visibility of the December 2001 image is not good, due to atmospheric effects. These include cloud and shadows on the western part of the project area and on the eastern part of the Ton Nam Yao forest unit. The dark appearance of some parts of the image caused by the topography and the sun angle makes the reflectance values of the objects inside them different to the reflectance values of the objects outside of them. The Normalized Difference Vegetation Index (NDVI) was introduced into the classification of this image (Townshend and Tucker, 1981). The NDVI is a ratio of the difference between the near infrared and red bands, showing the maximum and minimum difference of digital counts of individual pixels between two bands. NDVI is presented as a bounded ratio value ranging from –1 to +1 (Meijerink et al., 1994). The larger the NDVI the denser the vegetation.

$$NDVI = (NIR - R) /(NIR + R) \qquad (1)$$

Land cover types such as water, bare soil, low density green vegetation and senescent vegetation are associated with negative or low values. Higher values relate to photosynthetically active cover.

### 4.3.3 Creation of training sets

Training sets are areas representing each known land cover type that appear fairly homogeneous on the image. The spectral characteristics of each training set are used to determine class boundaries and pixel assignments in the supervised classification. For this study, 55 and 42 training areas with a polygonal form were digitized from the False Color Composite (354/BGR) of the April image and December image respectively. The training statistics were calculated and their histograms were adjusted to get the normal distribution model for each class. This is necessary for the supervised classification.

### 4.3.4 Maximum Likelihood Classification

This is one of the methods of supervised classification popular for use in remote sensing, in which a pixel with the maximum likelihood of correspondence is classified into the class they best fit (Japan Association on Remote Sensing, 1993). This method uses the spectral band covariances of the training sets to determine the orientation and relative elongation of the p-dimensional probability distribution around the mean of each class (Wilkie and Finn, 1997). This classification requires a large number of suitable training areas.

High likelihood pixels are classified into classes based on the probability function. The likelihood (Lk) is defined as the posterior probability of a pixel belonging to class k (Japan Association on Remote Sensing, 1993).

$$Lk = P(k/X) = P(X/k)/\Sigma P(I) * P(X/I) \quad (2)$$

Where Lk : the likelihood of any pixel belonging to class k

P(k) : prior probability of class k

P(X/k) : conditional probability to observe X from class k, or probability density function

The April image was classified, based on 55 training areas, into 12 categories. The December image was classified, using 42 training areas, into 14 categories.

### 4.3.5 Test of Classification Accuracy

The classification accuracy is a statistical means to determine how well the classification was done (Congalton, 1991). A common procedure is to compile a confusion matrix where the classified pixels and the ground truth pixels are tabulated in rows and columns. The overall accuracy of the supervised maximum likelihood classification is 88.6 %.

The burnt areas are separated well from other land cover types, showing the greatest accuracy of 99.8 %. Confusion between different land use/land cover types have resulted from differences in the spectral signatures of various surface covers and the limitation of pixel size. For example, The confusion between young litchi orchards and scrub or grass is a result of the mixed reflectance from the bare ground under the vegetation in these areas. The unregistered existence of orchards in the areas classified as dry evergreen forest is a result of spectral similarity between these features in some localities.

### 4.3. 6 Evaluation of Areas burnt by fire

It is traditional practice for farmers to start burning fields before the dry season (Apichart, 2002-personal communication). It will not be possible to determine which scars are true uncontrolled burn scars in agricultural fields or merely fields burnt as part of crop preparation from the April image because this is the season of field preparation. It is anticipated that these burnt areas will be overestimated due to fields burned in agricultural preparation being misinterpreted as true burn scars. Therefore, mainly the December image was used to detect burnt areas from agricultural fields. Not all burnt areas could be derived from the December image, because of cloud cover. The actual burnt areas in 2002 were determined using a mathematical function on classified April and December images to produce the map showing burnt areas.

Assessment of areas burnt in each forest unit is the data most frequently requested by the project manager. This data facilitates effective planning. This was carried out by applying an "INTERSECT" function to the burnt map and the forest unit map in a GIS program.

## 5. RESULT AND DISCUSSION

The April image was classified into 12 categories as shown in Tables 3 and Figure 2. Mixed deciduous forest, which accounts for 47.75 % of the total area, is the largest category. Grassland and scrub account for 20.28 % and 2.42 % of the land area respectively. The agricultural landuse categories, consisted, in order of descending size, of mixed crops accounting for 8.66 %, paddy fields which accounted for 1.12 % of the total area, and orchards accounting for 0.5 % of the total area. Burnt areas account for about 21 square kilometers (2 %) of the total area.

The degree of severity of forest fires during 1994-1997 was not high. The risk of fire in later years is strongly related to this low value. The high occurrence of fires in 1998 was associated mainly with the fuel accumulation from previous low risk years. In addition the drought conditions and heavy agricultural activities of 1998 accelerated the ignition of fires in that year.

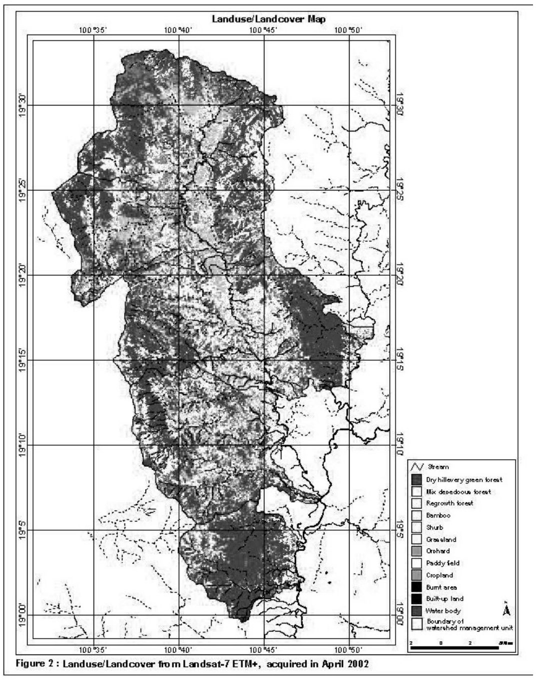


**Figure 2: Land Cover Types from Classified April (2002) image**

**Table 3: Land Cover Information from the classified April image**

| Land Cover Type | Area | |
|---|---|---|
| | Sq.km | % |
| 1.Dry Evergreen Forest | 60.95 | 6.05 |
| 2. Mixed Deciduous Forest | 480.89 | 47.75 |
| 3. Regrowth | 19.27 | 1.91 |
| 4. Bamboo Forest | 111.87 | 11.11 |
| 5. Scrub | 24.33 | 2.42 |
| 6. Grassland | 204.24 | 20.28 |
| 7. Paddy field | 11.23 | 1.12 |
| 8. Mixed crops | 87.21 | 8.66 |
| 9. Mixed orchards | 5.06 | 0.50 |
| 10. Built-up | 1.53 | 0.15 |
| 11. Water bodies | 0.42 | 0.04 |
| 12. Burnt | 21.36 | 2.08 |
| Total | 1,028.36 | 100.00 |

Table 4 and Figure 3 show the burnt areas according to forest unit. It is noted that 2002 burnt areas were 187.53 square kilometers less than those which occurred in 1998.

**Table 4**: **Burnt areas (2002) in each forest units**

| Unit No | Name of Forest Unit | Area (sq.km) | % |
|---|---|---|---|
| 1 | Khun Nam Prik | 5.07 | 0.5 |
| 2 | Huay Nam Yod | 1.36 | 0.13 |
| 3 | Nam Yao | 6.46 | 0.64 |
| 4 | Nam Hui | 2.84 | 0.28 |
| 5 | Nam Han | 4.45 | 0.44 |
| 6 | Nam Sobsai | 0.90 | 0.09 |
| | Total | 21.07 | 2.09 |

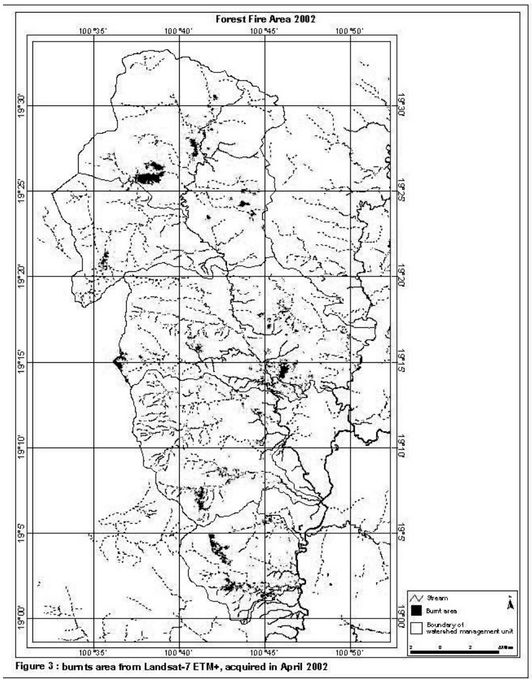


**Figure 3: Map showing burnt areas in the Upper Nan Watershed in 2002**

## 6. CONCLUSIONS

This study reveals that remote sensing, GIS and field survey techniques are best used for evaluating areas damaged by forest fires in the upper Nan watershed. The reduction of burnt areas, from 209 square kilometers in 1998 to 21 square kilometers in 2002 indicates the effective management and planning of forest fires in this region. There are some problems in carrying out this research, which can be addressed as follows: (1) the 30 meters resolution of the satellite data prohibits the interpretation capabilities, thus reducing the classification accuracy; (2) the complex terrain of the study area has limited the accessibility to some damaged areas, which are good representative for fire mapping; and (3) the presence of clouds in the study area has reduced the classification accuracy. It is suggested to use multi - resolution satellite data, such as IKONOS and SPOT. The RADAR image is recommended to use in conjunction with other optical image data for future research for avoiding the atmospheric effects such as haze and clouds.

## 7. REFERENCES

Andersen, J. R., E. Hardy, J. Roach, and R. Witner, A land use and land cover classification system for use with remote sensor data. U. S. Geological Survey, Paper 964, 1976.

Chavez, P. S., C. Guptill, and J. A. Bowell "Image Processing Techniques for Thematic Mapper Data", *Technical Papers*, 50th Annual Meeting of the American Society of Photogrammetry, Vol. 2, 728-742, 1984.

Congalton, R. G. A review of assessing the accuracy of classifications of remotely sensed data, *Remote Sensing of Environment*, Vol. 37, 35-46, 1991.

http://www.gistda.or.th

http://landsat7.usgs.gov/about.html.

Horler, D. N. H. and F. J. Ahern, Forestry Information Content of Thematic Mapper Data:, *International Journal of Remote Sensing*, Vol. 7(3), 405-428, 1986.

Japan Association on Remote Sensing, *Remote Sensing Note*. Nihon Printing Co. Ltd.: Tokyo. 284 pp., Tokyo, 1993.

Meijerink, Allard M. J. , de Brouwer Hans, A. M., Mannaerts, Chris M. and Valenzuela C. R. *Introduction to the use of Geographic Information Systems for practical Hydrology*, International Institute for Aerospace Survey and Earth Sciences (ITC), Publication No. 23, 1994.

Townshend J. R. G., Regionalization of terrain and remotely sensed data. In: *Terrain Analysis and Remote Sensing*. J. G. R. Townshend ed. Unwin, 109-132, 1981.

Wilkie, D. S. and Finn, J. T., *Remote Sensing Imagery for Natural Resources Monitoring: A Guide for First-Time Users*, Columbia University Press, New York, 1997.

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